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ENERGY FROM THE FARM

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The current U.S. transition period from a past of abundant, low-cost energy raw materials to a future of limited supplies, higher prices, and more reliance upon foreign suppliers has generated increased interest in agricultural farm crops and their byproducts and chemical feedstocks. Complete or major dependence on petroleum and natural gas for the foreseeable future is no longer possible, or economically feasible.

Plants, through photosynthesis, provide directly or indirectly our food, feed, and fiber, and through derivatives in fossil form, have produced reserves that supply almost all energy used by developed countries. Our dependency on the capacity of plants to convert solary energy through the basic biochemical processes that reduce carbon dioxide in the air to the building blocks of natural raw materials is, therefore, total. Our future, and that of the civilized world, may thus be dependent on better use of existing crops and modification of the plants and their environment for maximum utilization of solar energy.

The future adequacy of natural resources, based on agriculture, is controversial. Certainly food production will dominate our thinking, and many proponents insist that U.S. agriculture must be devoted entirely to the production of food. However, in the past, improvements in production, processing, and marketing, have supplied increased United State and world needs. We can optimistically say that, through research, continuing increases and more efficient production and use of biomass can be expected.

There are 200 to 300 commercial crops in the United States, of which 80 to 90 can be classed as major crops. Yet, there are at least 250,000 botanical species in the world. Chemical composition of the plant kingdom is largely unexplored. It is technically feasible to use or develop renewable raw materials for practically any fuel, chemical, and industrial use. It is primarily a question of economics. Ethyl alcohol from biomass, for example, is an excellent liquid motor fuel that is now under commercialization.

CEREALS

Cereal grains are the United States' most abundant raw materials produced by cultivation. The average composition of the most common ones are shown in table 1. They all contain starch as the principal

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component. Starch can be readily converted to ethyl alcohol by fermentation, as shown in figure 1.

TABLE 1.—AVERAGE COMPOSITION OF CEREAL GRAINS[1]

[In percent]

Grain	Starch	Protein	Oil	Fiber	Other constituents[2]
Hard wheat	64	14	2	2	18
Soft wheat	69	10	2	2	17
Dent corn	72	10	2	2	11
Sorghum	71	13	2	2	11

[1] Moisture-free basis.
[2] Minerals, sugars, pentosans, and vitamins.

The theoretical yield of ethyl alcohol per pound of starch is 0.568 pound. In actual commercial practice, yields generally are 90–95 percent of theoretical. Corn is the major U.S. cereal crop, and has become the basis for most current evaluation on the production of ethanol from cereal grains (starch). About 2.6 anhydrous gallons of alcohol can be produced from a bushel of corn. Representative production of cereal grain in 1978 was as follows:

U.S. production of cereal grains, 1978

	Tons
Corn	198, 000, 000
Wheat	54, 000, 000
Sorghum	21, 000, 000
Rice	6, 900, 000

Manufacture of ethyl alcohol from lower quality grains, surplus grains, or grain process byproducts, is the most promising source of alternate motor fuels for the next 5 to 10 years.

RESIDUES AND BYPRODUCTS

All crops produce residues; their availability and location are of major importance. With current advanced farming techniques, most residues remain in the field after harvest. Some residues must remain on the land for fertility and erosion controls. However, the total quantity is large, amounting to about 2 times the primary crop.

Representative U.S. residues and their distribution are shown in figures 2, 3, 4, and 5.

Crop byproducts and animal residues are not now used industrially to any great extent. However, most crop byproducts are highly cellulosic. Cellulose (a carbohydrate) can be converted to ethyl alcohol by fermentation, and offers future significant potential for this use as a chemical feedstock. Some of these potentials are shown in figure 6.

Anaerobic fermentation of organic materials, such as animal residues to biogas (methane, CO_2, other gases), could provide significant energy raw materials as shown in figure 7. Gas produced by this process contains 50 to 70 percent methane. The amount of biogas generated depends upon the type of residue and operating conditions. Quantities

range from 3 to 13 ft^3/lb of dry matter. Generally, a ton of dry residue will yield about 10,000 ft^3 of gas.

NEW CROPS

Potentially, there are unlimited new crops for energy. These are fast-growing crops such as kenaf, roselle, sorghums, and crotalaria. Chemically, these fiber crops are similar to wood, and their annual production rate is high. Kenaf yields of 10 to 25 dry tons per year have been experimentally achieved (figure 8). They may contribute significantly to future energy from the farm.

SUMMARY

The future of natural renewable raw materials from the farm as energy and chemical raw materials is excellent. There is every reason to believe that large volumes will be available if the technology is developed and the economic incentive is provided.

NEW CROP OPPORTUNITY

Of the 250,000 botanical species: From 80 to 90 produce crops in the United States worth more than $1 million; only 200 to 300 are used for commercial crops.

Past efforts, largely agronomic and to generate new varieties. The chemical composition of plant kingdom is largely unknown.

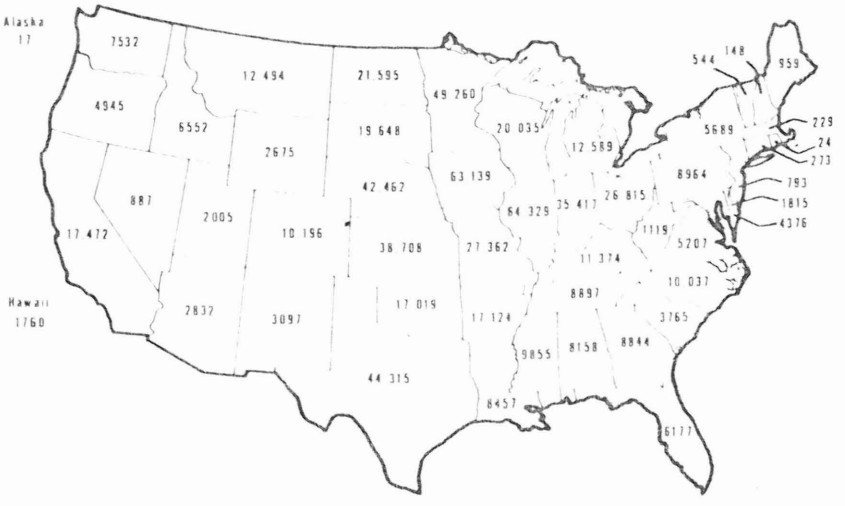
$$(C_6H_{10}O_5)_n + nH_2O = nC_6H_{12}O_6$$

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow 2\ C_6H_{12}O_6$$

$$C_6H_{12}O_6 \longrightarrow 2\ C_2H_5OH + 2\ CO_2$$

FIGURE 1

U.S. Agricultural Residues and Byproducts -- Quantities and Locations



1977

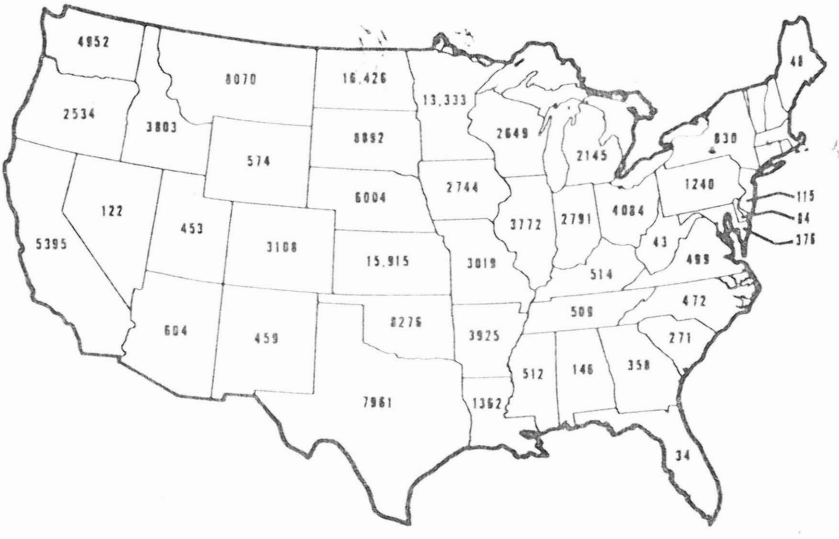
U.S. Department of Agriculture

Agricultural Residues

Total U.S. 677,988 × 1000 tons

FIGURE 2

U.S. Agricultural Residues and Byproducts -- Quantities and Locations



1977

U.S. Department of Agriculture

Straw

(Flax, Wheat, Rye, Rice, Oats, Barley)

Total U.S. 139,424 × 1000 tons

FIGURE 3

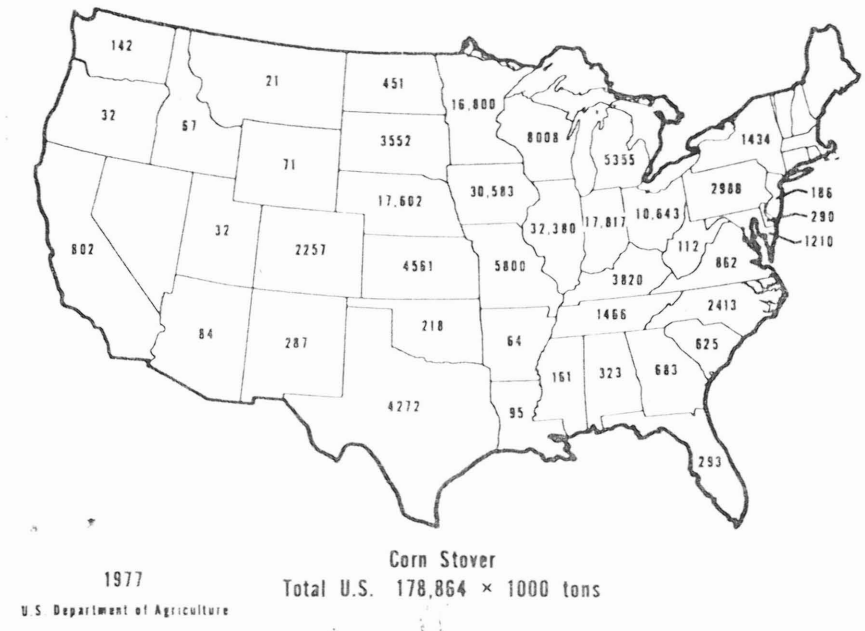


FIGURE 4

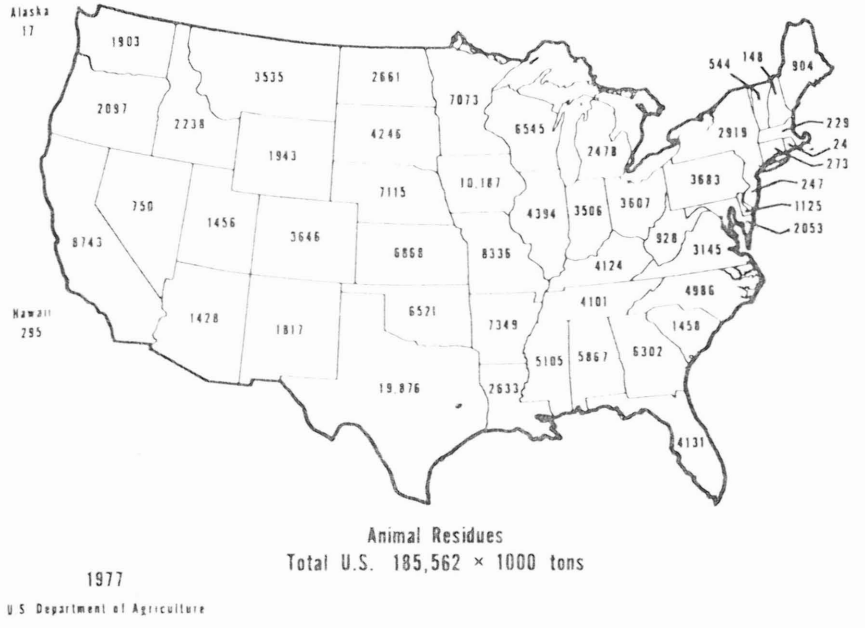


FIGURE 5

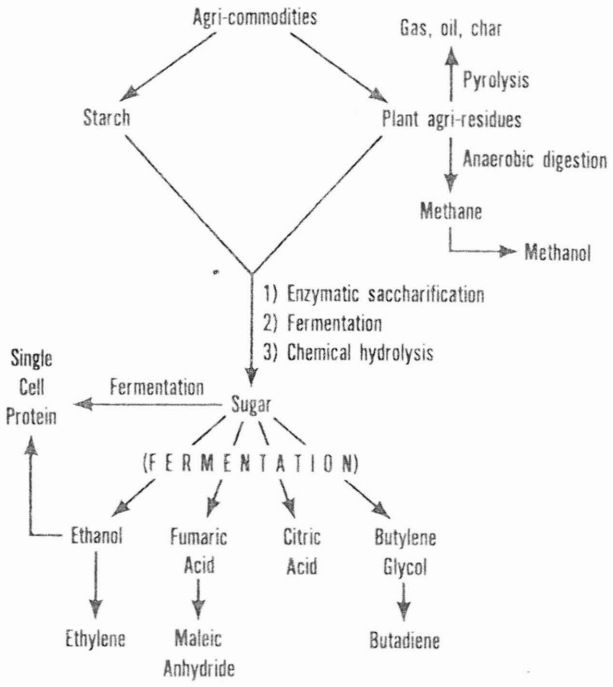


FIGURE 6

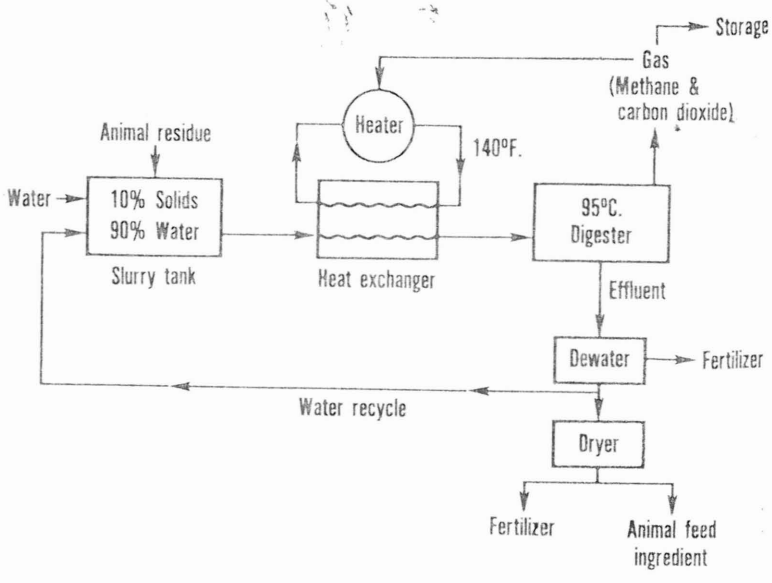


FIGURE 7

FIGURE 8